# URBAN GULLIES IN SÃO LUÍS CITY, MARANHÃO STATE, BRAZIL

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## 1. Introduction

Urban gully erosion is a serious problem in São Luís City, Maranhão State, Brazil. São Luís Municipality covers 831.7 km? and is situated in west-central Maranhão Island (2º19'09"-2º51'00" S; 44º01'16"-44º19'37" W). The Municipality is bounded by: São José de Ribamar (east); the Atlantic Ocean (north); Paço do Lumiar (west) and Rosário (south). The total population of the Municipality is 867,968; the vast majority being resident in urban areas (867,690) (IBGE, 2001).

The occurrence of soil erosion involves a series of inter-related contributory factors, including: rainfall erosivity, soil erodibility, slope characteristics and vegetation cover. Urban gully erosion in São Luís City has resulted in loss of lives and property. Environmental conditions (soil properties, soil use, rainfall regime and slope characteristics) combined with deforestation and unplanned and unauthorized urban settlement expansion has promoted land degradation and initiated gully formation (Guerra and Hoffman, 2006). The lack of basic urban infrastructure, especially sanitation, adequate road drains and paved roads, has exacerbated the problem.

In São Luís, a research project commenced in 2000, in which actively eroding gullies were identified and their evolution subsequently monitored. These gullies are in the districts of *Salina*, *Sacavém, Araçagi*, *Castelão*, *Bequimão*, *Coeduc* and *Jaracaty*.

## 2. Factors affecting gully erosion

Areas where people build houses in a high-density and irregular way are more susceptible to land degradation and particularly gully erosion. In São Luís there are several contributory physical factors, including the friable nature of sedimentary rocks, steep local slope angles and rainfall seasonality. Combined with poorly planned and rapid urban growth, these factors have contributed to the onset of severe accelerated erosion.

Local geological formations are composed of sedimentary rocks, dominated by permeable and generally friable and porous sandstones and shales of the Tertiary *Barreiras* Formation. Weathering on these rocks produces erodible soils, including lithosols, latosols, concretionary red/yellow clay soils and concretionary plinthosols (Maranhão, 1998). Thus, erodible soils and regolith are subject to high erosion rates, especially on steeper slopes subject to additional human interventions. Furthermore, although regional slopes are quite gentle, there is localized high relative relief.

Local vegetation consists of mangrove swamps, riparian forests, secondary mixed forest (*capoeira*), brushwood and water meadows. Secondary mixed forest and brushwood are the dominant vegetal cover adjacent to the urban gullies.

The local climate is humid tropical, with average annual temperatures of 26ºC, reaching higher values in October to December and lower from April to June (Fonseca, 1995). Rainfall distribution throughout the year is irregular, marked by two very distinct seasons (rainy and dry). The highly seasonal erosive rains incise a complex series of soil erosion landforms (including rills, gullies, pedestals, alcoves, grooves, pipes, sand-falls, clod-falls, ribs, fissures, and mass movements).

The settlement of São Luís was established in 1612 and has evolved in distinct phases. Rapid urban growth was associated with industrialization in the second half of the 18th Century. Rapid population and urban growth has intensified problems, compounded by poor planning and improper soil use. São Luís, like many other Brazilian cities, has experienced rapid population growth in recent decades, which has created a series of socio-economic and environmental problems, including accelerated soil erosion.

## 3. Monitored gullies

The selected monitored gullies are located in four points in the urban area of São Luís, representing specific land use types. These are: adjacent to irregular settlement (*Sacavém* District), coastal areas (*Ponta da Areia* Beach), a protected environment area (*Sítio Santa Eulália*) and next to *Castelão* Football Stadium (*Barreto* District).

The gullies have been monitored following the method of Guerra (1996), which employs stakes around the gullies, measuring tapes to measure the distance between stakes and gully edges and a Brunton compass to orientate measurements.

Monitoring at three selected gullies (Castelão, Sacavém and Salina) shows that the rainfall regime strongly

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contributes to gully evolution rates and gully retreat. Most erosion is attributable to erosive rains during and after the rainy season (Mendonça *et al*., 2005). Deforestation and burning of vegetation exposes soil to the direct impact of rain drops, causing soil crusting, decreasing infiltration and thus increasing runoff and accelerating erosion rates.

Sacavem Gully has the highest erosion rate of the monitored gullies, with a gully head retreat rate of ~1 metre per year. The other gullies have smaller retreat rates of ≤0.5 m per year. The main explanation is the high population pressures adjacent to Sacavem Gully. These pressures include a dense and intensively used network of footpaths (which form important source areas for runoff and sediment) and extraction of sand and gravel for building material.

## 4. Strategies for erosion control

In association with the ongoing programme of gully monitoring (Guerra *et al.*, 2004), efforts are in progress to rehabilitate degraded areas using bioengineering techniques. These techniques have been applied in different situations, with positive results from the use of biodegradable materials (e.g. vegetal fibres, wooden stakes and re-vegetation). These techniques stabilize the soil at low cost and improve the environment. Bioengineering involves the planned, strategic and phased application of selected materials, involving biodegradable materials, often in combination with 'hard engineering' structures constructed from stone, concrete and steel.

Currently, particular attention is focused on the use of biodegradable geotextiles made from the fibre or straw of some native palm trees, such as Buriti (*Mauritia flexuosa*). The use of these biogeotextiles is an adaptation of techniques used in other places with similar vegetation. For instance, in The Gambia (West Africa) the native palm tree Borassus, which is similar to Buriti, is being used in a similar fashion. Currently, a project is rehabilitating degraded areas in the Sacavém gullies, using bioengineering techniques. Preliminary evaluation suggests the approach has considerable potential as an efficient, effective and viable technique that offers environmental and financial advantages for the local people (Furtado *et al*., 2005).

The use of palm-geotextiles is a good solution for the environmental problems associated with soil degradation by gully erosion. The Buriti palm was selected due to its abundance in Maranhão, particularly in Barreirinhas Municipality, where the fibre is harvested to produce the mats. Furthermore, the Buriti fibres are similar to Borassus. However, the potential of other species of Brazilian palm to control urban gully erosion is also being evaluated in São Luís.

After engagements with community leaders, weekly classroom and field-based lessons have been provided for children and youths from impoverished backgrounds. A 'learn-whilst-doing' methodology is applied, which includes art-design lessons and theatrical performances, to underpin the theme of the classes and promote interesting and practical sustainable remediation techniques. This is enhancing the personal development of the young people (notably, technical training, behavioural improvements, improvement in self-esteem and self-belief, plus the development of a teamwork ethos), which has widened community participation by attracting other family members to attend project events and develop an affiliation with the sustainable development and remediation of degraded areas.

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